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CONCEPT FOR A LUNAR AND ASTEROID SAMPLE RETURN FACILITY

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The objective of this European Space Agency study was to examine an initial concept and requirements for a Lunar and Asteroid Receiving Facility (LaARF). Then to investigate the evolution from a facility dealing with only Moon and asteroid returned sample material, to a facility dealing with Mars returned sample material with potential biohazard.

The LaARF concept and requirements were broadly derived from requirements including Infrastructure, Equipment, People & Knowledge. The facility concept was required to deal with samples from a number of possible missions returning from asteroids or the lunar surface. A number of past and planned missions were outlined to draw both general features that can be used to develop the concept, and more importantly to derive the range of likely hardware and samples to be handled by the facility. Requirements for the general sample quantity and make-up were that the facility should accommodate 500g of samples comprising dust, grains and rocks of varying composition and sizes.

The initial concept was evolved using review of literature and inputs from a dedicated Concept Definition Workshop involving scientific and industry experts. A functional architecture was established and technologies & techniques were assessed. It was recognised that tele-operations are especially needed. Information flow through the facility was analysed.

Commonality with a Mars Sample Receiving Facility (MSRF) was assessed and possible evolutions to a MSRF were considered. Then Scenario Definition Workshops were held with leading scientists and industry experts to determine the optimal scenario to evolve the LaARF to an MSRF. The result of this analysis was that independent facilities without ‘future-proofing’ prior to expansion were the optimal solution. This approach maximised the potential future capability in a cost-efficient manner.

Finally, analysis of potential users for the facility showed that Planetary Protection (PP) hardware samples, meteorites and planetary analogues were the most promising users for a shared facility. Non-space samples, such as those from widely dispersed geological collections, may also benefit from the facility.

I. INTRODUCTION

One of the ultimate goals of exploration missions is to return material samples from other Solar System bodies. Space Agencies such as NASA and JAXA have already successfully carried out sample return missions to the Moon, comets and asteroids. They have therefore had to respond to the immediate and very specific need of properly curating those materials. They have built Sample Return Facilities where these extra-terrestrial samples are received, curated and through controlled processes are distributed to the wider science community for research, while continuously ensuring

the scientific integrity of the samples. As a consequence such facilities not only rely on extremely clean and monitored conditions, but also on handling techniques and diagnostic tools adequate for the different types of samples in terms of size, shape and composition.

The European Space Agency (ESA) has not yet launched a sample return mission, but is pursuing this possibility through studies for Marco Polo R and a Mars sample return mission. Independent of the initiator of the mission, it is important that ESA have a comprehensive understanding of the main design drivers, critical technologies and suite of capabilities

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needed to fulfil the functional requirements of a Sample Return Facility (SRF) for the various types of samples. In the frame of the Mars Sample Return mission, dedicated studies have been performed to identify a set of initial functional requirements as well as a concept definition for a Mars Sample Return Facility (MSRF)¹. A Mars Sample Return mission is classified as a 'Category V' restricted mission under the COSPAR Planetary Protection Policy², and the resulting requirement to contain the sample is a major driver for the design and thus the cost of such a facility. However, these requirements can be relaxed for a SRF aimed at Moon and asteroid samples.

The aim of this study was to provide a concept for a Lunar and Asteroid Receiving Facility (LaARF), identifying the minimum set of capabilities needed for each type of sample received as well as the impact of additional capabilities that could arise from widening the user community. The study looked at the various scenarios to accommodate both a Lunar and Asteroid Receiving Facility and a Mars Sample Return Facility within Europe.

II. CAPABILITIES

At the beginning of the study a set of capabilities required by the facility were defined. These involved both the building infrastructure and the people working within it. These capabilities would be developed later into non-technical 'user requirements'. They included:

Safety - The Facility shall present no hazard in its operations to the health and welfare of the users. The Facility shall present no hazard in its operations to the local and worldwide environment.

Science - The Facility shall allow sample characterisation to be conducted on the material by scientists.

Interoperability - The Facility shall receive all returned sample material from all European lunar and asteroid missions and sample sets from other Agency missions.

Expandability - The Facility shall receive all returned sample material from all European moon, comet and planetary missions and sample sets from other Agency missions.

Capability development - The Facility shall promote the development of European scientific expertise, European scientific infrastructure and European technology.

Availability - The Facility shall be available for the conduct of science without periods of significant downtime (240 working days per year).

Education and public outreach - The Facility shall provide education and public outreach.

Flexibility - The Facility shall be readily adaptable to the needs of sample material from non-space users

Security - The Facility shall securely store sample material.

Standards - The Facility shall comply with all standards relevant to its use.

The initial requirements for the LaARF samples were defined by ESA to be: "the facility will be able to accommodate 500g of samples comprising dust, grains and rocks of varying composition and sizes".

III. PREVIOUS AND FUTURE MISSIONS

The facility concept was required to deal with samples from a number of possible missions returning from asteroids or the lunar surface. As the particular missions that may result in returned samples have not yet been selected, a review of previous and future missions were considered to draw together general features to develop the concept and the range of likely hardware / samples to be handled by the facility.

For comparison, the requirements for the LaARF samples were defined by ESA to be: "the facility will be able to accommodate 500g of samples comprising dust, grains and rocks of varying composition and sizes".

III.I Previous Missions

Apollo - Lunar sampling of large variety of regolith rock and cores. 382kg of samples were collected in various human handled containers during six missions.

Soviet Luna - 326g of drilled lunar core samples were collected for three missions.

Fobos-Grunt - This was a mission to collect 85-160g Phobos regolith samples, but the spacecraft failed to leave Earth orbit.

Stardust - NASA mission which collected 10000 particles in the 1-300µm size range from the coma of Jupiter family Comet 81P/Wild2 which were returned to Earth in 2006 and are curated at NASA-JSC³.

Hayabusa - 1500 grains of asteroid regolith were collected in a single sample container. Head gas was collected during opening⁴.

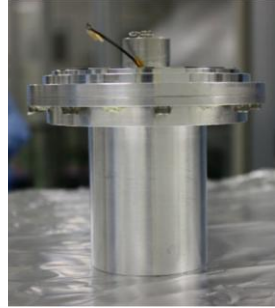


Figure 1 : Hayabusa sample return capsule after landing in Australia (left) and Hayabusa sample container prior to opening (right)⁴

III.II Future Missions

Marco-Polo R – ESA M3 mission to collect 3 samples of asteroid regolith and rocks in small sample vessels. These sample vessels are stored inside a container⁵.

OSIRIS-Rex – NASA mission to collect 1 sample of 60g of asteroid regolith in a Stardust type Earth Return capsule⁶.

MSL-2020 – NASA Mars Science Laboratory now has sample caching for a Mars sample in its baseline design.

Hayabusa 2 – JAXA follow on mission to collect asteroid regolith and subsurface samples using a penetrator. A single sample container will be used again⁷.

Phootprint – A proposed ESA sample return mission to Phobos to collect surface regolith and core. Its design is TBD⁸.

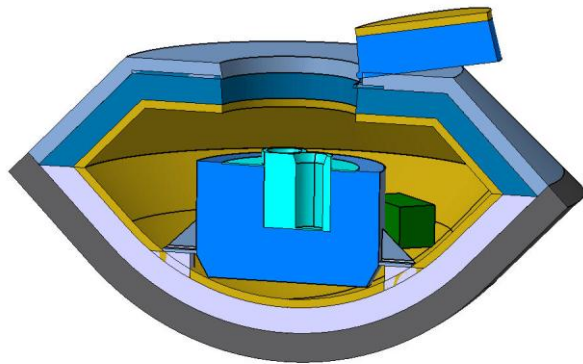


Figure 2 : Marco-Polo R concept for return capsule⁴
N.B. the innermost container is the sample vessel

IV. FUNCTIONAL CONCEPT

The concept has been evolved using a review of literature and via inputs from workshops involving the

authors of this paper. An overall diagram showing identified “Functional areas” and interfaces between them was developed during the scenario definition workshops (Figure 3).

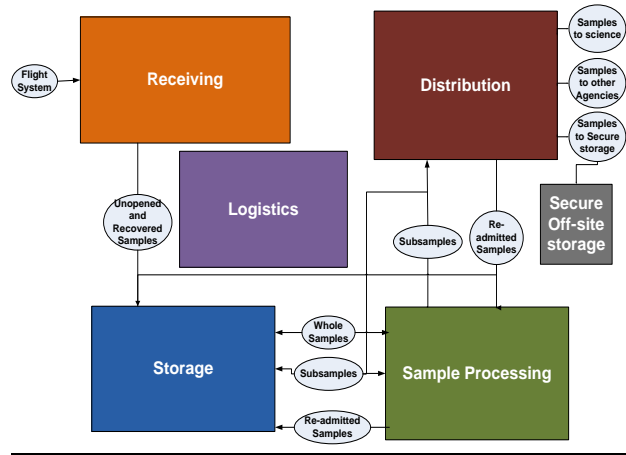


Figure 3 : Functional Block Concept of the facility

IV.I Receiving

On arrival at the facility, the first function will be to inspect the hardware and determine its condition. Inspection may also be carried out at several different points, in parallel with the opening and cleaning functions. The inspection process should also involve ascertaining the state of any seals on the returned hardware prior to opening. The receiving function will include cleaning to reduce contamination levels to match the facility. The flight hardware is opened to sample vessel level and the interior conditions are determined. In-vessel characterisation, ie: the determination of the state of the samples inside the vessel, is performed to allow the selection of samples for storage and processing.

IV.II Storage

Unopened samples are sent from receiving to the storage section. In this there are four types of storage:

1. Unopened storage – to allow for storage of unprocessed samples (which have been characterised in-situ, by eg: CT scans) and to store designated ‘legacy’ long term samples.
2. Working storage – to store characterised samples designated for subsampling and sub-sampled samples.
3. Readmitted storage – to allow for storage of readmitted samples ie: those samples returned from scientific institutes after examination.

4. Associated item storage – used to store processed flight hardware, instrument calibration samples and witness samples.

The storage would provide monitoring of environmental parameters including temperature, pressure, humidity and cleanliness. It would allow for rapid filing and retrieval of samples at any time.

IV.III Sample Processing

Some initial characterisation of the samples will be undertaken within the facility using non-destructive techniques to determine:

- is the sample solid, liquid or gas?
- if solid, is it composed of chips or powder, or a single coherent sample?
- if a single coherent sample, how heterogeneous is it?
- what is its texture (grain-size, grain-boundary geometry, presence of void spaces, veins)?
- what is its composition (relative proportions of silicates, sulphides, metal)?

The sample processing section will be capable of subsampling any sample down to any size, identifying the subsample and preserving the remainder of the sample. Both the new subsample and the remainder of the sample would then be re/packaged in their containers for storage.

IV.IV Distribution

The distribution function covers all processes following sub-sample collection involved in the distribution of material outside the facility. The main recipients will be members of the international scientific community applying to study the sample. But other possible destinations are a secure repository for unopened samples or other Agencies which may have an agreement for a portion of the returned sample.

The sample must be packed, labelled and sent out to the correct location. The distribution function is also responsible for re-admitting any analysed sub-samples back into the facility.

IV.V Logistics

This function covers the day to day running of the facilities including:

- Security - to prevent unauthorised access to the samples and to protect against external environmental effects.
- Health and Safety – to adhere to the relevant national regulatory framework.
- Maintenance – to schedule and plan for planned and unplanned maintenance.

- Tracking – to maintain a database of samples to ensure that samples are correctly identified and in order to preserve the maximum amount of sample
- Education and Outreach – this should be provided for the public, schools, colleges and research institutions.

V. ENVIRONMENTAL REQUIREMENTS

The environment within the facility is one of the key factors in ensuring that the sample integrity is maintained long term. The “environment” is taken to include temperature, pressure, atmospheric gas mix, humidity, terrestrial contamination levels, mechanical influences (e.g. vibration and shock), and in sensitive areas, electromagnetic influences.

The aim is to maximise sample preservation whilst minimising stress on the facility design (i.e. what is the minimum environment that is acceptable).

V.I Temperature

It is desirable to avoid considerably raising or lowering the sample temperature on entry to the facility. The samples will already have been exposed to temperature cycling, both over their in-situ existence (e.g. on a rotating body exposed alternately to sunshine and shadow), and probably during the cruise and entry phase on the return, and whilst awaiting recovery.

Current facilities store samples at ambient temperature. However, samples returned from locations with the presence of ice may require cold temperatures to prevent the boiling off of volatiles of interest. It is therefore expected that there be an option to store samples both in unopened and working storage below ambient temperature. Processing of the samples can be done at ambient temperature, but as with storage, the option to perform the characterisation and sub-sampling at lower temperatures should exist.

V.II Pressure

Any Moon or asteroid samples will come from a high vacuum environment, and although sample return canisters may be designed to preserve this environment, it cannot be guaranteed, especially given re-entry stresses. Re-pressurisation may cause condensation issues and absorption of contamination if not performed in a controlled manner.

The majority of currently curated extra-terrestrial samples are stored and handled at slight positive pressure to their surroundings, and this is the baseline for the LaARF. A vacuum approach would provide minimal gain in science with a significant increase in complexity⁹.

Some Apollo samples have, however, been maintained in their original environment. If a sample is to be maintained in its original vacuum state, than this

should be done via preservation in its original flight container. The transition to ambient pressure of other samples should be controlled. The opening environment for the incoming flight hardware will therefore need variable pressure, and be matched to the interior conditions of the container to be opened to prevent sudden pressurisation / de-pressurisation. The Hayabusa facility made use of a variable pressure isolator during opening⁵.

V.III Gas

The primary concern when considering the gas mix is long term exposure to reactive gases which may degrade the sample. The mix must also not place undue stress on the operation of equipment to be used within the facility, and also ideally not require the maintenance of extensive infrastructure to maintain.

Storage areas for unopened and working samples should maintain an inert atmosphere (e.g. N₂). Processing areas should ideally be at the same conditions.

V.IV Particulate contamination

The threat of contamination by inorganic material to the samples is of high concern. The mineralogical and chemical compositions of the samples are of great importance to the scientific community, and the samples would be kept and handled in a low particulate environment. ISO 4 environments have been used for the storage of past extra-terrestrial samples^{10,11}. Maintenance of positive pressure around the samples, and physical barriers separating them from the external environment would also be implemented.

V.IV Organic and biological contamination

There is particular interest in any organic contents of samples and so organic contamination would be closely controlled. Human contact is the largest source of organic contamination, and so the sample should be protected from operators. Organic contamination can also come from problematic materials used within the facility (as well as airborne sources). The use of plastics and lubricants for equipment would be controlled to ensure that they are not introducing unwanted contamination. Biological contamination is not considered a great threat to the sample, and the procedures used to minimise organic contamination would need to be sufficient to protect it from microbial contamination.

V.V Other

Relative humidity would need to be controlled. Levels would be monitored and if humidity strays beyond permissible limits an alarm would be triggered.

Brief physical shocks as well as longer term vibration of the sample should be prevented.

Mechanical shock may destroy the structure, or cause unwanted mixing of samples. This should be avoided by careful sample handling.

Large electromagnetic fields should be avoided as these could destroy the magnetic properties of the sample which may hold information on sample origins (e.g. residual magnetism from exposure to large magnetic fields during formation).

VI. SAMPLE FLOW IN THE FACILITY

Figure 4 shows the flow of operations in the facility. The process is mapped against the functional areas discussed above. The important interfaces are between the working storage and the processing functions and through the dissemination process. These will see frequent exchange between the areas and so require a robust and uncomplicated relationship to ensure procedures are not unduly taxing or risky to the sample.

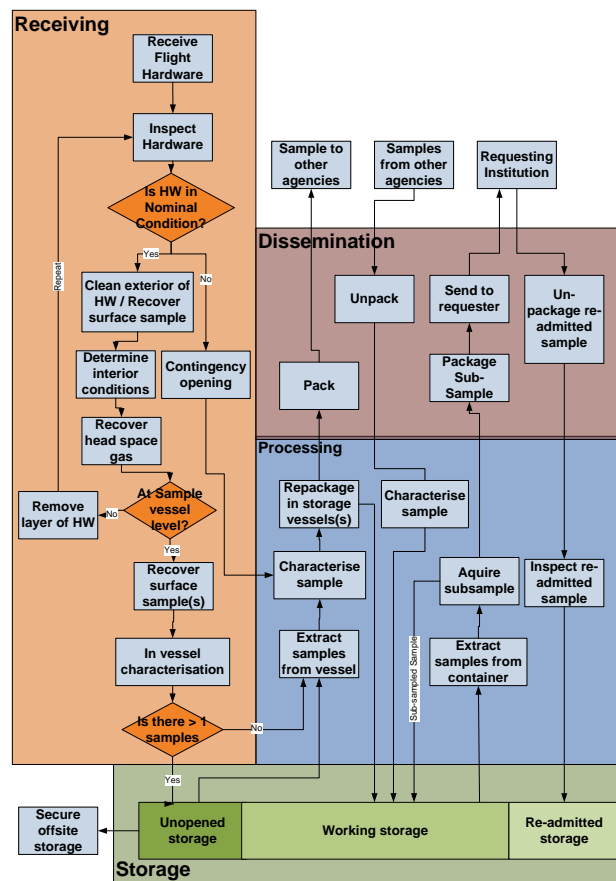


Figure 4: Flow diagram of operations in the facility.

VII. INFORMATION FLOW ON THE SAMPLE

It is considered vital that all information on the sample is kept and linked to the sample. It was therefore proposed that each sample should have a 'passport',

containing all the information gathered so far about the sample and the conditions it has been exposed to.

Figure 5 shows the information flow around the facility. The figure shows where information is generated and where it is required at all points in the sample handling process, from collection to investigation.

Ultimately, all data is stored in the central sample database that contains the sample “passports” along with linked data that may be of relevance (e.g. Flight hardware design, facility construction information). Required data will be drawn from this central data repository when needed, although on the diagram, specific data linkages are shown to inform what processes require what specific information. It will be ultimately data drawn from this database that informs the science community of the samples in the facility and allows them to define what subsamples they need for their investigations.

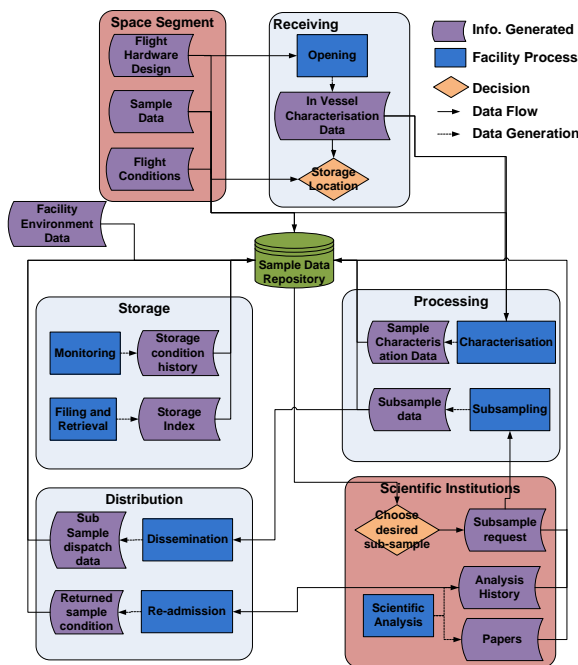


Figure 5 : Information Flow within the facility.

VIII. SAMPLE HANDLING

The challenge was to prevent contamination of the samples from terrestrial sources and also prevent contamination of the Earth by the sample material. Whilst there are well established techniques for isolation and contamination control the requirement to do both simultaneously requires a different approach.

Whilst traditional cleanrooms protect the samples, the introduction of human operators during sample manipulation makes the control of contamination difficult. The sample is exposed to contamination and

the manipulation processes can cause contamination of the space shared by the sample and the operator.

Thus the approach of removing the operator from the space by the use of robotics, and the use of negative pressure double walled isolators, with positive pressure interface to the ambient environment, provides a solution to the dual problems of isolation and containment.

The use of robotics does not ensure contamination is eradicated. The mechanical systems must be well cleaned before installation, and must minimise material shedding from joints and contamination from lubricants and contact materials. The case for human glovebox handling (Figure 6) versus mechanical or tele-operation was discussed for each section of the facility.



Figure 6 : Lunar Sample glove box at JSC⁶

VIII.I Receiving

Flexibility was considered important here as the flight hardware might arrive in a damaged or unexpected state, so the opening and handling operations would be prepared for this. Precision handling is not a prominent issue, as only the external containment hardware is handled. Contamination control is important, but can be considered slightly reduced in importance, as the samples themselves are always maintained in the flight hardware. The trade-off comes down marginally on the side of tele-operation, although this will depend on the opening environment. A low pressure opening environment such as used during the Hayabusa mission will demand tele-operation due to the impracticality of gloves in a low pressure box. The case for automation in this area is really mission-dependent.

VIII.II Storage

Contamination was the key issue here, as the samples are stored long term, and adverse contamination can build up over time if introduced regularly. Precision is not an important driver but ease

of operation is relevant, as this will be more frequent. No particular sample handling options are favoured here. It is debatable whether the added cost and complexity of automation would be appropriate.

VIII.III Processing

Once again, contamination was the key issue here, as the samples are directly exposed to the operational environment. Precision is required, as samples are handled and sub-divided and sizes down to individual dust grains (few microns in size) may need to be handled. Ease of operation is important as well, as the operations are both frequent and complex. This area is a potential area for a shift to tele-operation over more traditional glove-boxes, with added precision and operational advantages, as well as better contamination control.

VIII.IV Distribution

Most of handling and operations would be of sub-samples and were not expected to be too onerous. Contamination must be avoided to prevent degraded or damaged sub-samples being dispatched. Tele-operation would be a suitable solution, although packing of the samples could potentially be performed at the sub-sampling stage.

VIII.V Cross Contamination

Care should be taken when handling samples to minimise cross contamination between different sample types, or different sample locations. This could be achieved, for example, by thorough cleaning of equipment between samples, or by having dedicated equipment for different sample types

VIII. SAMPLE CHARACTERISATION

Table 1 gives a description of the likely instrumentation in the facility required for the physical and chemical characterisation of the samples to inform the scientific community of what materials are available.

Instrument	Characterisation
High resolution optical imaging	Sample type and morphology
RAMAN Spectroscopy	Chemical structure and composition
CT Scan	Sample heterogeneity
FT-IR Spectroscopy	Phase Composition
SEM	Mineralogy, Gas composition
	Visual data, particle size distribution, density.
Weighing scales	Mass

Table 1: Suggested characterisation equipment

IX. HEALTH AND SAFETY (H&S)

The design of the Moon and Asteroid Sample Facility would be similar, in regulatory terms, to those clean rooms used in pharmaceutical and electronics industries. Evolution to a Mars facility does increase H&S regulation complexity, due to the more stringent requirements under Planetary Protection protocols.

X. NON SPACE USE

Other potential non-space users for the facility have been assessed. There are many potential candidates for example meteorites, ice cores or biological samples. However, after a comparison of the requirements for each category of samples, it was decided that Planetary Protection (PP) hardware samples, meteorites and 'planetary analogues' were the most promising users for a shared facility.

XI. EVOLUTION TO MARS SAMPLE RETURN FACILITY

XI.I Commonality of requirements

In planning the LaARF, the evolution of the facility to become a Mars Sample Return Facility (MSRF) was considered. The design of this was based on previous ESA studies^{12,13}. It was necessary to compare and contrast the requirements for the two facilities. The key differences were:

- The need to contain the sample in a high biohazard level environment (MSRF only)
- The need to characterise the biohazard of the sample (MSRF only)
- The rapid distribution of the sample outside the facility (LaARF only)
- The possible use of the facility for other, non-space applications. (LaARF only)

XI.II Commonality of equipment

The MSRF was a facility design equipped to handle biohazard at the highest level through-out, whereas the LaARF design was only for a clean facility. This resulted in different requirements for pressure regimes within the facility, positive pressure in the LaARF laboratories, and negative pressure in the MSRF, and different standards for the building infrastructure itself. The MSRF was also expected to use doubled walled isolators with a positive pressure envelope to deal with issues of contamination in a negatively pressurised environment. This would need to be considered in the case of the facility evolution.

Both had similar processes involved in receiving the flight hardware and opening the sample container and vessels (the vessels are the innermost level). The opening process for the Mars sample container would be

more complex due to the additional levels of seals. It is certainly possible that equipment could be re-configured to fit both processes.

The contained nature of the MSRF called for more tele-operation in an effort to remove humans from the process and improve biocontainment safety. Although this is by no means excluded from the LaARF, the drive towards tele-operation is not a strong in all areas.

The MSRF design had considerable additional analytical resources specifically aimed at biohazard assessment and microbiological investigation; however, both facilities shared a similar set of non-destructive initial characterisation equipment.

XI.III Evolution scenarios

For all evolution scenarios, the following are assumed to be true:

- The first facility to be built will be the LaARF. Then there will be an interval of some years, (5-10 years are assumed), before the beginning of the MSRF build.
- The LaARF requires clean room type infrastructure only.
- The MSRF requires biocontainment at the highest level. To achieve this, a building with concrete shell and embedded membrane as the biocontainment barrier has been proposed [8].
- A 'shoebox' type standard container is used for the reception of samples and transport medium.

The possible evolution scenarios discussed between architects, health and safety specialists and scientists were:

A. Independent facilities

The two facilities are on different sites and possibly in different countries. It will be possible to learn some lessons for the MSRF from the building of the first (LaARF) facility, but that staff and systems will all be completely separate, as they will be operating at the same time.

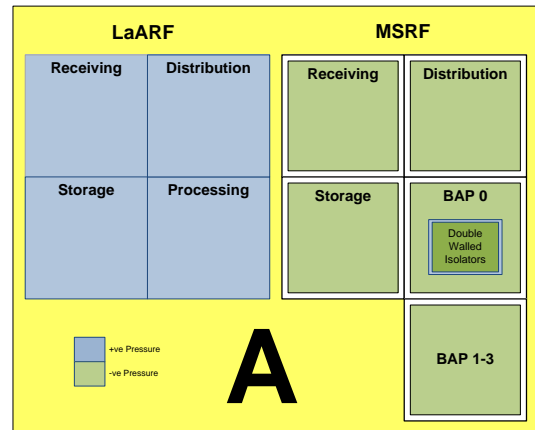


Figure 7: Option A: Independent facilities

B. Conjoined with common reception and opening facilities

In this option, Lunar, Asteroid and Mars samples would all be brought to one building. The building would be designed to accommodate two separate facilities with a common receiving facility. The receiving function would include the reception of the flight hardware and the opening of it. So the facilities share operations from Flight hardware reception until sample extraction. From this point on the samples would move into separate areas for storage, characterisation and distribution.

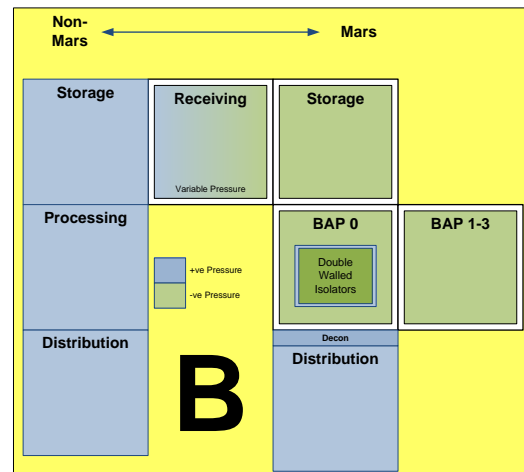


Figure 8 : Option B: Conjoined with common reception and opening

C. Conjoined with common Reception, Opening, and sample handling facilities.

The entire LaARF would be designed with a later Mars use in mind. For example, the facility structure would need to incorporate a membrane, and all surfaces would have curved edges and smooth surfaces to facilitate decontamination. Storage and processing areas would operate at negative pressure to the environment at all times. For lunar and asteroid processing, operations would be done in positively pressurised glove boxes / isolators. Mars sample handling would be performed in double walled isolators and handling would be largely automated.

D. a) Integrated through upgrading

In this scenario, the facility is built for Lunar and Asteroid samples, but has the potential to be upgraded to handle Mars samples. The facility would be upgraded by constructing a bio-containment shell (for instance using a steel shell or specialised concrete) around the facility. Modules could be added to the facility later.

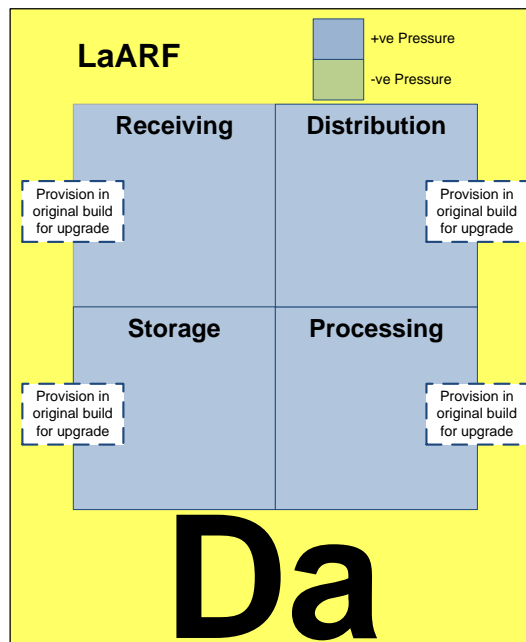


Figure 9 : Option Da: Integration through upgrading

b) Integrated through refurbishment

In this scenario, the facility is built for lunar and asteroid samples, without considering the MSRF. If desired, the LaARF could be closed and completely refurbished to be made suitable for handling Mars samples.

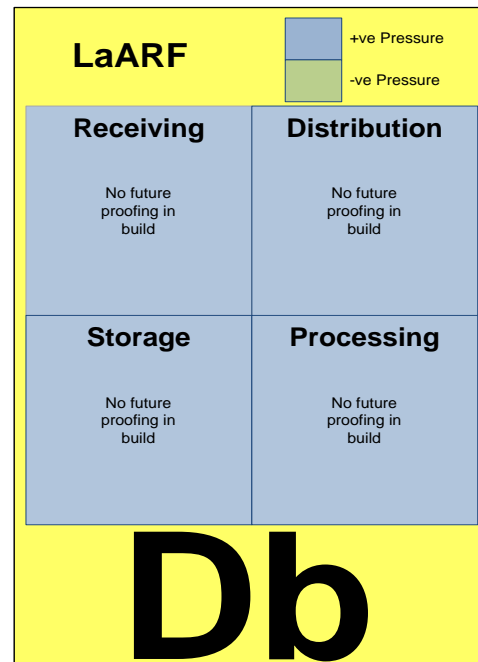


Figure 10 : Option Db: Integration through refurbishment

XI.IV Conclusions

After a careful trade study carried out with all elements of the team participating, the most favoured scenario was 'A' - independent facilities. This was driven by the importance accorded to the following criteria: initial cost, safety, science, user operability, flexibility and time to evolve.

Scenario 'B' was second as it offered low initial cost, potentially good science, flexibility, user operability and time to evolve. Scenario 'C' consistently came last in the trade study, due to its high initial cost and potential negative impacts on safety and science.

XII. FUTURE DEVELOPMENTS

XII.I Science of Samples

An Analogues Working Group could be established to gather and define a comprehensive set of planetary analogues. The Planetary Analogues could be curated in the Planetary Analogue Centre which could be the first element of the LaARF.

The Planetary Hardware Centre could be the second element of the LaARF which would contain the planetary hardware samples such as contamination witness samples, allow the testing of sample handling equipment. It is foreseen that hardware manufacturers could bring their equipment to the centre, where they would test their hardware with an appropriate analogue, then analyse the effect on the analogue from a scientific

point of view (i.e. undesirable contamination, loss or important structure etc.).

The meteorite collection would be the last space science element of the LaARF.

In parallel a Non-Space Working Group could consider and encourage the use of the Facility by Non-Space users. The Non-Space Materials Centre could house geological samples with a high scientific value.

Training is required for the people in the facility and it is foreseen that an approach similar to NASA Johnson Space Centre (JSC) might be used. Finally, it is considered that the Education & Outreach Centre could run from the beginning of the project.

XI.II Equipment development

For the Equipment development it is assumed that an asteroid sample (e.g. Marco-Polo) would arrive at the earliest in 2021 and a Mars sample would arrive at the earliest in 2027.

Early development was required for:

- Ultraclean Tele-Operations
- Science instrument interfaces (not requiring bio-containment measures)
- Decontamination/cleaning technologies with validation

It is expected that training personnel and developing techniques and equipment would be required in time for the returned Marco-Polo samples with ultra-clean and bio-containment training in time for MSR samples.

XIII. CONCLUSIONS

The initial concept developed for LaARF is a functional architecture that takes into account the building, equipment, people and knowledge. It includes sections for receiving, storage, processing, distribution and logistics. Particular attention was paid to environmental conditions in the facility. Current technologies have been assessed and it is recognised that tele-operations are needed, particularly during sample processing.

After examining various alternatives, it was decided that the optimal scenario to evolve the LaARF to a Mars Sample Receiving Facility (MSRF) would be to design two completely independent facilities.

Analysis of potential non-space users for the Facility identified that Planetary Protection (PP) Hardware Samples, meteorites & planetary analogues were the most promising users for a shared facility. There is considerable analogue expertise in Europe and the facility could therefore deliver significant science prior to the return of any samples.

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